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Investigating Factors Affecting Solar Photovoltaic (PV) Adoption among Malaysian SMEs

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ABSTRACT

This study investigates the factors affecting solar PV adoption among Malaysian small and medium-sized enterprises (SMEs), focusing specifically on manufacturing. The study employed Technology-Organisational-Environmental (TOE) model as a research framework. The study hypothesised that owners'/managers' technology readiness (innovativeness and optimism), relative advantage, organisational readiness, and government support play a significant role in the adoption of solar PV. Data were gathered from 69 manufacturing SMEs and analysed using Partial Least Squares (PLS) Structural Equation Modelling (SEM). The findings demonstrate a significant influence of owner's/managers' technology readiness (innovativeness and optimism) and relative advantage on a firm's adoption of solar PV. Meanwhile, organisational readiness and government support were not significant predictors of the adoption. The study's findings can be helpful to policymakers (e.g., the government) and solar authority bodies [e.g., Sustainable Energy Development Authority (SEDA)] in Malaysia to design effective strategies, programs, and incentives to promote solar PV adoption in the manufacturing sector. The study further suggests that the efforts to promote greater adoption of solar PV among firms should be capitalised on its perceived benefits. In short, consistent with the government initiative to promote a more sustainable environment using renewable energy sources such as solar PV, this study offers an insightful perspective to understand the acceptance of this renewable energy solution among the industry players, specifically the SME sector.

1. Introduction

Malaysia has been identified as among the key players in promoting renewable energy, following the lead of other countries' green initiatives. The primary reasons for this push are to reduce the nation's dependence on imported fossil fuels and address climate change concerns [1]. Renewable energy involves utilising advanced technology to convert natural sources into usable energy to substitute traditional sources [2]. Using alternative sources of renewable energy is highly recommended by researchers and scientists as it is pollution-free and highly economical [3,4]. The

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use of renewable energy helps to reduce the emission of greenhouse gas and thus lower the global warming effect [5].

Renewable energy in Malaysia is a critical element in developing green technologies, which aligns with the government's efforts to achieve a low-carbon economy [6]. Renewable energy sources, like solar photovoltaic (Solar PV), large hydropower, biomass, biogas, and small hydropower, are viable alternatives due to the country's abundant natural resources [7]. Solar PV emerges as one of the most substantial sources of renewable energy, specifically for countries that receive considerable amounts of solar irradiation [5,8,9].

The potential for deploying solar energy in Malaysia is significant, given the monthly average of 400 – 600 MJ/m^2, making it an ideal location for establishing solar power plants [10]. Solar energy can be categorised into three main types: electricity or photovoltaic (PV), thermal, and photovoltaic-thermal [11]. Solar PV technology involves harnessing the sun's energy using solar cells or photovoltaic cells and converting it into electricity through the photovoltaic effect. It can be installed on residential rooftops and commercial building walls as a grid-connected PV application [12]. Meanwhile, thermal solar technology converts solar energy into heat [13].

In 2013, the energy sector emerged as the main driver of Malaysia's GDP, representing 63.1% of the total GDP [7]. The ministry suggests that by diversifying resources and exploring alternative energy sources, such as renewable energy, the sector can further strengthen the development of green technologies.

Abdullah *et al.,* [14] highlight that businesses can benefit from incorporating a solar PV system by reducing their electricity bills, protecting themselves from electricity rate hikes in the future, and contributing to a greener environment. Given the anticipated annual increase of 4.5% in electricity tariffs in Malaysia, adopting the solar PV system helps businesses to reduce operating costs, particularly in electricity bills, while generating additional cash flow [14]. In addition, using solar PV systems provides a marketing advantage to businesses by incorporating green practices, enabling the company to promote green innovation and gain profitability [15]. The Green practices can be categorised into (i) green products and processes, including technological advancements in producing green products, (ii) utilisation of green energy, and (iii) waste recycling to prevent pollution [15]. By embracing green practices, businesses narrow the gap between economic growth and environmental conservation effort.

A cost factor is the key challenge of installing solar PV systems among businesses. The businesses must install solar PV panels and all the necessary components on the premises' rooftops. Despite higher expected return on investment, the initial cost outlay and maintenance requirements may hinder small businesses from adopting solar PV. As a result, the adoption of solar PV among Malaysian small and medium-sized enterprises (SMEs) is far below the government's target. As SMEs make up 1,226,494 (97.4%) of Malaysian registered businesses in Malaysia, their role in driving green technology initiatives is crucial [16].

Despite considerable scholarly works delving into issues surrounding the adoption of renewable energy initiatives, most of these studies have focused on the use of solar PV systems amongst individuals or residential consumers. Earlier studies have explored consumer perceptions or acceptance of solar PV amongst the domestic consumer in various countries, such as UAE, India, China, Greece, and Nigeria [17-23]. Similarly, studies conducted in Malaysia, including those by Lau *et al.,* [1] and Muhibbullah *et al.,* [24], also gained insight into the challenges and issues of renewable energy initiatives.

Although the commercial or business sector reportedly consumes more energy than individual consumers and other sectors, limited research reported on adopting solar PV as a renewable energy alternative among business organisations, particularly SMEs, in Malaysia [25]. Therefore, the study investigates the factors affecting solar PV adoption among Malaysian SMEs, specifically in the manufacturing sector. Exploring the perceptions of Malaysian SMEs, particularly on identifying key contributing factors to the deployment of solar PV, would provide valuable insights, given the significant role of SMEs in Malaysia's economic growth. As Malaysia's second largest contributor to economic growth, the manufacturing sector is crucial in promoting sustainable development [26]. In addition, industries have greater energy consumption than individual consumers. Consequently, encouraging the more active deployment of alternative renewable energy sources among firms would accelerate the government agenda towards a green and sustainable environment.

This paper is structured as follows. The next section reviews solar PV literature and reports on prior studies' findings. The research model and hypotheses development are presented in section three. Section four explains the study's methodology, including the unit of analysis, participants, data collection procedure, and measures adapted for the study. Section five reports the model testing, focusing on the measurement and assessment models used in the study. The following section then discusses the findings of the study. The paper concludes with a discussion of limitations and suggestions for future research in the final section.

2. Literature Review

2.1 Solar PV in Malaysia

Rapid energy development has accompanied the rapid growth of Malaysia's economy [27]. This development indicates that the country's reliance on the energy sector will likely increase as the country progresses towards industrialisation. Malaysia's energy sector is expected to expand further to support its socioeconomic well-being and enhance its export earnings. Due to its proximity to the equator, Malaysia has access to receive a high amount of sunlight throughout the year [28].

An earlier initiative to promote solar energy adoption among Malaysian via solar PV rural electrification programme started in 1992 by equipping 100 houses in remote areas with solar PV systems [1]. The solar PV system is a technology that can effectively capture solar energy to produce significant amounts of clean, domestically secure, and environmentally sustainable electricity [12]. Another program, Suria 1000, implemented between 2006 and 2010 to subsidise successful bidders in setting up solar systems at their premises, created wider opportunities for domestic and industry players to participate in solar energy initiatives.

Solar PV has become a viable alternative energy source for business and domestic consumption in the 21st century due to its potential benefits [29]. According to Abdul Latif *et al.,* [30], solar PV systems are among the leading green technologies for converting solar energy into renewable energy. Its simple installation process on building rooftops or walls distinguishes them from other renewable energy sources requiring more complex technology. Furthermore, the low cost of solar PV systems makes them appealing to small businesses [31].

Although solar PV installation can provide advantages to individual consumers for their energy consumption, it is projected that an industry sector, including SMEs, will benefit more due to their significant dependence on electricity for their operations. With more than 97% of established business entities in Malaysia, SMEs can benefit substantially by installing solar PV systems to reduce their electricity costs while supporting environmentally friendly practices. SMEs could reduce operating costs and improve cash flow by lowering monthly electricity bills. Additionally, this could help protect the business from future uncertainties related to electricity tariffs. By demonstrating a commitment towards producing clean energy and supporting a sustainable environment, SMEs can also promote their business to customers.

In line with the National green technology plan, multiple measures have been implemented to encourage renewable energy usage amongst SMEs [7]. These measures include, among others, the National Energy Policy (NEP), the National Bio-fuel Policy of 2006, the National Green Technology Policy of 2009, the National Renewable Energy Policy of 2010, and the Green Technology Master Plan for 2017-2030. Furthermore, renewable energy and the green economy have been listed among 15 critical activities for economic expansion under the Shared Prosperity Vision 2030, the Malaysian government's plan to transform the country into a thriving Asian Tiger [32].

To ensure the success of these initiatives, the Malaysian government has collaborated with public-private partnerships and private financiers like the Sustainability Energy Development Authority (SEDA). In 2016, SEDA introduced the Net Energy Metering (NEM) program to support renewable energy generation by installing solar PV systems. SEDA opens the program to all residential, commercial, industrial, and agricultural participants. SEDA also developed the NEM calculator to estimate the potential monthly savings, upfront expenses, simple payback period, and environmental benefits of solar power generation [33].

The ministry set the NEM programme quota at 500 MW in 2019, with 450 MW allocated to commercial and industrial buildings and 50 MW for residential buildings [34]. By implementing this programme, the country is expected to generate more electricity to meet current demands [35]. As the initial cost of installing solar PV systems can be prohibitively expensive for some applicants, the government has introduced incentives to encourage businesses, particularly SMEs, to adopt renewable energy sources, such as solar PV.

Regardless of various measures to promote the use of green technologies and their substantial potential for the national agenda, the use of green technologies by SMEs in the manufacturing sector remains low [7]. In 2015, it was reported that Malaysia had approximately 3,400 green manufacturing SMEs. By 2030, the Government aims to increase the number of green manufacturing SMEs twofold [7]. Musa and Chinniah [36] found that Malaysian SMEs are only motivated to adopt green technologies if doing so gives them a competitive advantage. Thus, this study explores the factors influencing the uptake of solar PV systems among SMEs in Malaysia.

2.2 Prior Studies of Solar PV Adoption

A literature review revealed a scarcity of research on adopting renewable energy among organisations. Earlier studies in renewable energy adoption have centred on exploring individual users' attitudes, intentions, and acceptance of renewable energy [2,37-44]. For instance, Alam and Rashid [2] examined the perception of Klang Valley users towards using renewable energy. Meanwhile, Azlina *et al.,* [40] investigated Malaysian households' willingness to pay for renewable energy. The study discovered that Malaysian families, on average, are willing to pay approximately RM3.22 (USD.82) per month for renewable energy.

Othman *et al.,* [41] further assessed Malaysian residential consumers' adoption of green technologies (smart vehicles, solar PV, smart metering, and battery storage technology). The study revealed that awareness, pricing, knowledge, and income are crucial to predict intention to adopt green technologies. Similarly, Zahari and Esa [44] found that the consumer perception of the utility of new technology, the utility of renewable energy, and the benefit of new technology as other significant predictors.

In recent years, there has been a growing interest in researching the adoption of renewable energy, including solar PV, in organisational contexts. White *et al.,* [45], for example, investigated the practice of an Environment Management System (EMS) in non-profit and SMEs in the United Kingdom. The study suggested that the system enables the organisation to identify operational improvements while significantly improving its environmental performance, lowering its annual carbon footprint, and gaining new business. Meanwhile, Geh *et al.,* [46] investigated the factors influencing solar PV deployment in Africa. The findings demonstrated the critical roles of direct and indirect benefits, societal effects, and relative advantage in deploying photovoltaic energy by public universities.

The construction industry is one of the major contributors to greenhouse gas emissions. Unuigbe *et al.,* [47], in their interviews with building experts in Nigeria, discovered that cultural differences and identity were essential factors in promoting solar PV adoption in this sector. In addition, a survey by Qamar *et al.,* [48] found that competitive pressure and high energy costs are key factors that impede SMEs' adoption of solar PV in Pakistan.

Similarly, limited studies have investigated factors influencing solar PV adoption among Malaysian SMEs [14]. Musa and Chinniah [36], for instance, highlighted that costs (e.g., high raw materials and initial investment) and lack of knowledge about environmental issues are major barriers to adopting green technologies among Malaysian SMEs. Vaka *et al.,* [49] supported this finding based on their comprehensive review of renewable energy initiatives in Malaysia. They discovered that a lack of knowledge and awareness of the potential return on investment and benefits of solar PV systems were among the key challenges of the adoption. Meanwhile, Yao *et al.,* [50] highlighted the importance of trust relationship networks and conflict coordination when adopting green technology in SMEs.

Due to the challenges mentioned above, SMEs may be unaware of their potential contribution towards environmental protection and may not participate in government initiatives related to environmental conservation. Additionally, SMEs that cannot handle the technologies and are uncertain about the anticipated return on investment may be hesitant to invest in green technologies.

As SMEs play substantial roles in Malaysia's economic growth, further understanding of the firms' perception of solar PV and the key contributing factors to its adoption is worth investigating. Hence, this study adopted a Technological-Organisational Environmental (TOE) framework by Tornatzky *et al.,* [51] to explore the issues. The framework suggests that the adoption and implementation of technological innovations by an organisation are impacted by factors from technological (T), organisational (O), and environmental (E) contexts. The technological context pertains to the technologies that apply to organisations, while the organisational context encompasses the size, scope, and availability of organisational resources. On the other hand, the environmental context refers to the external factors surrounding business operations.

From the technological context, relative advantage, compatibility, and complexity were the three common factors tested in prior studies as derived from Roger's Diffusion of Innovation (DOI) theory [52]. However, only relative advantage is tested in the present study. Solar PV technology is not directly compatible with the company's operation, values, and strategic goals. Hence, the technology may be perceived as an external tool for converting solar energy into electricity, which might not be viewed as directly related to the SME's machine operation. As a result, compatibility is not perceived as a significant factor in deciding solar PV adoption.

Similarly, complexity is not a major issue for solar PV adoption. Li *et al.,* [53] suggest that although companies cannot develop the technology, they can still purchase from providers. The complexity of solar PV technology primarily lies in its components and solar panels. Users (adopters) have the option to select a solar PV provider that can offer the installation service. Therefore, the emphasis would be on the usefulness and advantages of solar PV to the business rather than its technicalities and complexities.

As for the organisational and environmental contexts, many studies have emphasised the importance of organisational readiness and government support [54,55].

Owners'/managers' characteristics are essential in deciding whether or not to use an innovation. Moreover, the decision-making process in SMEs is typically centralised to the owners/managers, particularly Chief Executive Officers (CEOs). Ahn *et al.,* [56] suggested that organisations are more likely to use technology when the CEOs have a positive attitude, an entrepreneurial orientation, patience, and education in facilitating the technology deployment. Smith [57] further argued that a champion is required for innovation because it requires strong advocates who push for organisational-level changes and disseminate the benefits within organisations. As change agents, CEOs can help to promote change, overcome internal resistance, and break down institutional barriers [58].

In 2000, Parasuraman [59] introduced Technology Readiness Index (TRI), which employs a multiple-item scale to measure people's readiness to embrace new technologies. Technology readiness refers to "people's propensity to embrace and use new technologies for achieving goals in their personal and professional lives" (p. 308). The construct assesses an individual's general attitude toward technology and, as such, does not reflect their skill or level of experience with technology. The technology readiness (TR) construct comprises four dimensions: optimism; innovativeness; discomfort; and insecurity. Optimism reflects an individual's positive attitude toward technology, based on the belief that technology makes lives more efficient, flexible, and controllable [60]. Innovativeness refers to the ability to be a technology pioneer and assume thought leadership. The emotion of discomfort expresses a person's sense of being overwhelmed by technology. Insecurity stems from the belief that technology will not function properly. While optimism and innovativeness propel an individual's technology readiness (hence, motivators), discomfort and insecurity, on the other hand, suffocate it (therefore, inhibitors).

Blut and Wang [61] discovered that technology readiness is best conceptualised as a two-dimensional construct distinguishing between motivators (i.e., innovativeness, optimism) and inhibitors (i.e., insecurity, discomfort). They suggest that the motivators have stronger relationships than the inhibitors. Furthermore, technology readiness-technology usage relationships are affected by the type of technology (hedonic/utilitarian), organisation characteristics (voluntary/mandatory use; organisation support), and country context (gross domestic product; human development).

Several studies have analysed the role of technology readiness in connection with using technologies [61-66]. For example, Thong and Yap [66] highlighted the vital role of individual CEO characteristics in adopting technology. Other studies discovered the significant effect of technology readiness on ERP adoption [62,64]. In a survey of 102 Malaysian SMEs, Ramayah *et al.,* [65] discovered that owners/managers are neutral regarding their technology readiness. The results indicate that while they are optimistic and innovative, they also feel a great deal of discomfort and insecurity.

Given the importance of owners'/managers' technological readiness in adopting and using technologies, none of the existing studies has focused on solar PV technology in organisations, particularly in the Malaysian context. A study in a similar area by Hasheem *et al.,* [67] investigated factors that influence individual households' purchase intentions of solar PV technology in Pakistan.

3. Research Model and Hypotheses

The study's research model indicating the effect of selected technology (T), organisation (O), environment (E) factors, as well as owner/manager characteristics on solar PV adoption, is presented in Figure 1.

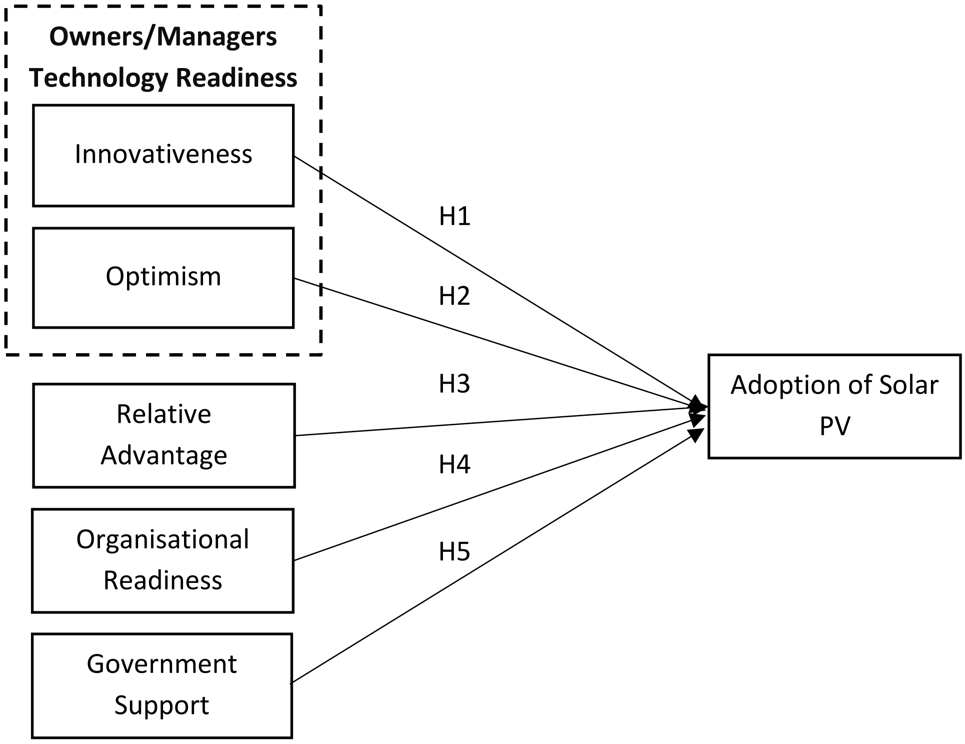

Fig. 1. Research Model

3.1 Owners'/Managers' Technology Readiness

According to Parasuraman and Colby [60], technology readiness pertains to individuals' willingness to embrace and use new technology to achieve their personal and professional objectives. In many SMEs, the owners/managers (CEOs) wield significant influence over the organisation's technology adoption [68]. The owners'/managers' characteristics determine the organisation's management structure [69]. Therefore, their qualities, such as innovativeness, information intensity, knowledge, and attitude towards technology adoption, play a critical role in determining SMEs' successful adoption of technology, given that they serve as the central decision-maker [66]. Ramayah *et al.,* [65] argued that adopting technological advancements in numerous SMEs depends considerably on the CEO's decisions. As a result, technology readiness, age, gender, and educational background, are critical CEO characteristics in ensuring successful technology adoption and installation.

In the context of renewable energy projects, Mustapa *et al.,* (2010) argued that the knowledge, information, and technology awareness of a CEO can significantly influence the decision to adopt the technology, specifically solar PV systems. Despite the government's various initiatives to achieve renewable energy targets, many SMEs lack awareness of solar PV systems and their potential benefits due to information and knowledge barriers, as noted by Mustapa *et al.,* [27]. This perspective is also supported by Musa and Chinniah [36], who found that insufficient awareness of environmental issues among CEOs may hinder SMEs' adoption of solar PV systems. Despite the critical role of CEO technology readiness in adopting new technologies, including solar PV systems, the specific impact of CEO readiness on the adoption decision is still largely unknown. As a result, the following hypotheses have emerged:

H1: CEO innovativeness is positively associated with solar PV adoption
H2: CEO optimism is positively associated with solar PV adoption

3.2 Relative Advantage

Relative advantage is the degree to which an innovation is perceived as more advantageous than its substitute idea or the innovation it replaced [55]. In another respect, relative advantage has been conceptualised as an organisation's perception that innovation provides a better option than other innovations currently in use [70]. The advantage refers to the benefits the organisation may obtain from using a product or innovation [71]. Hence, acceptance of the innovation tends to be reportedly higher for an innovation that promises extensive economic value over time and greater performance than similar technologies [72].

Solar PV, as one kind of technological innovation, is viewed as a reliable product due to its potential to increase customers' future savings on energy consumption and, ultimately, financial commitment to energy usage [19]. For SMEs, in case the CEO assesses greater benefits than the cost of adopting an innovation, the tendency to deploy the innovation is relatively higher [66,73]. More importantly, apart from the organisation's owner innovativeness and self-motivation, greater awareness and understanding of those potential benefits is crucial for the organisation's decision to embrace technology [74]. In the context of solar PV, the role of service providers is essential in creating the organisation's awareness and understanding of the solar PV benefits.

Despite unsupported findings in several studies, the crucial roles of perceived relative advantages on an organisation's adoption of solar PV technology have been reported in many studies and varying types of innovations [75]. The applicable studies include IT in SMEs and e-commerce in SMEs [71,73]. Similarly, Alshamaila *et al.,* [74] concur with the previous findings that relative advantage positively affects SMEs' adoption of cloud computing technology.

In green technology, the substantial influence of perceived relative advantage has been proven in many studies. To illustrate, Alam and Islam [37] investigated solar PV adoption among individual households. They confirmed that greater anticipated advantage of solar PV has led to a greater level of its adoption among consumers. The finding reflects the importance of ensuring the green innovation's reliability and utility level to ensure its acceptance. Similarly, Lin *et al.,* [72] and Zhang *et al.,* [76] also found considerable support for the positive effect of perceived relative advantage on the organisations' readiness to deploy green technology innovations. Meanwhile, Lin and Ho [77] corroborated their findings by revealing the positive effect of relative advantage, as measured by environmental and economic performance, on green technology practices in an organisation.

Having considered the potential benefits of using solar PV, researchers anticipate a greater tendency for organisations to consider solar PV technology when they perceive that solar PV offers considerable economic benefits and provides better efficiency in their operation. This argument is reflected in the following hypothesis:

H3: Relative advantage is positively associated with solar PV adoption

3.3 Organisational Readiness

Organisational readiness can be seen as the availability of resources supporting technology adoption and reflects the organisation's ability and willingness to embrace new technology [78,79]. In this regard, organisations must have sufficient information technology (IT) sophistication and financial resources to support the sustainability of such adoption [80,81]. Hence, the absence of organisational readiness could impede the success of technology adoption efforts [82]. For instance, Gangwar [83] emphasised that organisations must have appropriate infrastructures, technical abilities, and financial resources to adopt cloud computing successfully. Their study found organisational readiness as a significant predictor of perceived usefulness and ease of use of cloud computing adoption. Aziz and Yusof [84] suggested that organisational readiness can be viewed from two perspectives: commitment to change and effectiveness of change. At this point, Aziz and Yusof [84] summarised that the ability of a company to implement changes determines the effectiveness of change, with a high degree of change effectiveness can result in the company being physically ready for information systems (IS) adoption.

Organisational readiness is crucial for SMEs as they often experience financial constraints that can restrict their ability to adopt new technologies effectively. Hence, SMEs with higher organisational readiness are believed to be more likely to adopt technological innovations successfully. For instance, Ramdani *et al.,* [54] found evidence supporting the importance of organisational readiness in adopting enterprise applications among SMEs in the Northwest of England. A recent study by Lutfi *et al.,* [85] discovered that organisational readiness could enhance the capability of Jordanian SMEs to adopt big data analytics and leverage its potential benefits for digital transformation. Viewing through the lens of green innovation, Lin *et al.,* [72] indicated that a business has a better chance of adopting technology if it has qualified human resources. Their findings suggest that adopting green supply chain management among SMEs in Malaysia was significantly associated with the quality of their human resources.

SMEs' successful adoption of solar PV is heavily dependent on organisational readiness. Although solar PV is considered a sustainable and cost-effective energy source, its adoption requires substantial initial investments, which can be challenging for SMEs with limited financial resources. Therefore, SMEs must assess their organisational readiness, which encompasses financial resources and technical capabilities, to ensure the successful adoption of solar PV.

Given the significance of organisational readiness in facilitating the successful adoption of various technologies, this study anticipates a similar pattern for adopting solar PV. Specifically, SMEs with higher levels of organisational readiness are more likely to adopt solar PV than SMEs with lower levels of organisational readiness. Therefore, the following hypothesis is postulated:

H4: Organisational readiness is positively associated with solar PV adoption

3.4 Government Support

Innovation's success relies not solely on an organisation's resources but also on external factors that facilitate its adoption. Prior studies have emphasised the essential role of government support in facilitating technological innovation efforts within organisations [86-88]. Such support can create a conducive environment for businesses to adopt new technologies and view such adoption as beneficial. According to Nguyen *et al.,* [87], financial and non-financial support from the government can improve the likelihood of organisations accepting innovation. In this context, government support can stimulate the adoption of innovation through regulation and policies, financial incentives (e.g., tax incentives and subsidies), and guidance (e.g., training and technical support) [77,87,89].

Jeon *et al.,* [90] examined the factors affecting the adoption of e-business in Korea. They measured government support based on the amount and frequency of financial assistance received from the government. The study's findings showed that the level of government support for e-business was significantly higher for organisations that adopted e-business than those that did not. On the other hand, Park and Kim [88] noted the importance of government support and policies in adopting big data by Korean organisations.

Numerous studies have discovered the positive effect of government support on promoting and facilitating the uptake of green technologies. For example, Lin and Ho [77] studied the determinants of green practice adoption by logistic companies. They found evidence to support the crucial role of government support, especially in supporting small and medium-sized logistics companies to adopt green practices. The authors claimed that SMEs have limited resources; hence without external support from the government, they might not be able to pursue such adoption. Hwang *et al.,* [91] examined a green supply chain adoption decision in the semiconductor industry and emphasised the significance of government regulation in promoting sustainability practices. The potential for new environmental laws or explicit government endorsement for sustainable practices can serve as a significant incentive for organisations to initiate sustainability initiatives, highlighting the crucial role of governmental pressure in promoting sustainability practices. Government regulation in the context of their study includes standards, rules, procedures, and incentives established by regulatory entities and mandates compliance from individuals or organisations. The study suggested that companies in the semiconductor industry can benefit from complying with government regulations and implementing green practices in their supply chain operations.

Based on Malaysia's aspiration to achieve Low Carbon Nation Aspiration 2040, the adoption of solar PV is considered essential. Government support is seen as critical in promoting and supporting the adoption of solar PV. As a result, it is necessary to understand how government support can influence adoption decisions, particularly given the various incentives introduced by the Malaysian government to encourage solar PV adoption. Therefore, this study anticipates finding a positive association between government support and solar PV adoption, suggesting that SMEs that receive greater government support are more likely to adopt solar PV than those that receive less support. The following hypothesis is, therefore, hypothesised:

H5: Government support is positively associated with solar PV adoption

4. Research Methodology

The research design employed in this study was quantitative research, using a cross-sectional survey questionnaire to collect the data. The study focused on manufacturing SMEs in Malaysia, with the unit of analysis being the organisation. The classification of SMEs is determined based on two factors: sales turnover and the number of full-time employees (Table 1). Manufacturing SMEs are companies with annual sales of up to RM50 million or no more than 200 full-time employees [16].

Table 1
Manufacturing SMEs classification [16]

Micro	Small	Medium
Sales turnover of less than RM300,000 OR employee of less than 5	Sales turnover from RM300,000 to RM14,999,999 OR employees from 5 to 74	Sales turnover from RM15million to 50 million OR employees from 75 to 200

Manufacturing SMEs were chosen due to considerable energy usage in their production activities, which has a significant residual impact on the environment [92]. According to World Data Atlas [93], Malaysia's carbon dioxide (CO_2) emissions increased from 14.7 million tonnes in 1972 to 251.6 million tonnes in 2021, at an average yearly rate of 6.12%. Husaini and Lean [94] also found a positive correlation between electricity consumption and manufacturing output. They noted that the growth of the manufacturing sector leads to increased demand for electricity. The primary user of energy products in Malaysia, according to the 2015 report on the System of Environmental-Economic

Accounting Physical Supply & Use Table: Energy Account (MySEEA PSUT Energy), is the manufacturing sector, which consumed 18,683 kilotonnes of oil equivalent (ktoe) of energy.

4.1 Participants

Given that in small businesses, the chief executive manager is typically the owner/manager [66]. Therefore, this study selected owners/managers as the key informants. According to Ahn *et al.,* [56], the owners'/managers' characteristics play a significant role in SMEs' decision-making processes related to open innovation. In SMEs, adopting new technologies is often directed by the organisation's key person, typically the owner/manager.

The samples for the study were selected from the manufacturing companies listed under the Federation of Manufacturing Malaysia (FMM). Only SMEs were included from the initial list of 2,841 FMM members, resulting in a total sampling frame of 2,085. A stratified sampling approach was used to select the sample due to the varying numbers of manufacturing SMEs in each state. The sample was determined by choosing every 3rd number in the list, resulting in 576 samples.

4.2 Data Collection Procedure

Due to the Covid-19 pandemic, the questionnaire was distributed online using SurveyMonkey. Initially, the questionnaire was intended for the selected 576 samples. However, after three months, the response rate was very low, so the researchers distributed the questionnaire to all members in the sampling frame. The response rate remained low despite making phone calls to the 576 companies. As a result, 2,085 questionnaires were distributed to all SME manufacturing companies.

The survey received 99 responses. Of these, 16 (16.16%) respondents reported that they had already adopted solar PV, while 83 (83.84%) reported that they had not. However, 31 responses (8 non-adopters and 16 adopters) had more than 20% missing values and were excluded from the analysis. Additionally, six responses were from service companies and were also excluded. The final analysis was conducted with 69 responses, which included only non-adopters of solar PV. Among the respondents, 56.52% were male, 42.03% were female, and 1.45% were unknown. Most respondents (66.67%) were below 40, while only 31.88% were 40 or older. Information about gender and age was not provided by one respondent (1.45%).

The majority of the surveyed businesses were established after 2000 (34, or 49.28%) and are located in Selangor (30, or 43.47%) (Table 2). Regarding job positions, the highest percentage of respondents (36, or 59.17%) held top positions with less than ten years of experience (54, or 78.26%).

Table 2
Organisational profile

Demographic		No.	%
Year of establishment	1960 -1970	3	4.35
	1971 - 1980	2	2.90
	1981 - 1990	8	11.58
	1991 - 2000	15	21.74
	2001 – 2010	29	42.03
	2011 - 2020	5	7.25
	Unidentified	6	8.70
	Unsure	1	1.45
	Total	69	100.0
Position	Owner / Managing Director / CEO	10	14.49
	Manager	26	37.68
	Executive	32	46.38
	Unidentified	1	1.45
	Total	69	100.0
Sector	Basic Metals	12	17.39
	Chemical	6	8.70
	Electrical & Electronics	3	4.35
	Fabricated Metals	7	10.14
	Food, Beverages & Tobacco	11	15.94
	Furniture	1	1.45
	Machinery & Equipment	8	11.59
	Non-Metallic Mineral	1	1.45
	Medical, Precision & Optical Instrument, Watches & Clocks	1	1.45
	Paper, Printing & Publishing	3	4.35
	Recycling	1	1.45
	Textile, Wearing Apparel, Leather	1	1.45
	Others	14	20.29
	Total	69	100.0

Demographic		No.	%
Location	Johor	16	23.18
	Negeri Sembilan	3	4.35
	Kedah	3	4.35
	Pahang	2	2.90
	Selangor	30	43.47
	W.P. Putrajaya	1	1.45
	Perak	3	4.35
	Pulau Pinang	4	5.80
	Melaka	6	8.70
	Unidentified	1	1.45
	Total	69	100.0
Duration in current position	Less than 5 years	27	39.13
	5 – 10 years	27	39.13
	10 – 15 years	4	5.80
	More than 15 years	10	14.49
	Unidentified	1	1.45
	Total	69	100.0
Full-time employee	< 5 employees	2	2.90
	5 – 10 employees	29	42.03
	10 – 15 employees	33	47.82
	> 15 employees	4	5.80
	Unidentified	1	1.45
	Total	69	100.0
Sales turnover	Below RM300,000	3	4.35
	RM300,000 – RM999,999	9	13.04
	RM 1m – RM14,999,999	19	27.54
	RM 25m – RM50m	14	20.29
	More than RM50m	24	34.78
	Total	69	100.0

The largest proportion of manufacturing companies belonged to the basic metals category, accounting for 17.39% of the total. The majority of the manufacturing companies (92.75%) had a workforce of 5 to 15 employees, while more than half (55.07%) reported a sales turnover of more than RM25,000,000.

4.3 Measures

Validated measures for examining the factors influencing the adoption of solar PV were adapted from the literature review and used as the instrument in the study (Table 3). Innovativeness was conceptualised as the tendency to be a technology pioneer and thought leader. Optimism was conceptualised as a positive view of technology and a belief that it offers people increased control, flexibility, and efficiency. Relative advantage refers to the degree to which the adoption of solar PV benefits the companies. Meanwhile, organisational readiness was defined as the degree to which the company has the resources to support the adoption of a solar PV system. In contrast, government support refers to the degree of financial and technical support provided by the government and related agencies for adopting solar PV. Finally, adoption was conceptualised as the intention to adopt solar PV.

The constructs in the study were measured using a 5-point Likert scale ranging from (1) Strongly Disagree to (5) Strongly Agree. Based on feedback received during the questionnaire's pre-test, some items were reworded to improve clarity and understanding.

Table 3
Measures

Construct	Item		Source
OWNERS/MANAGERS TECHNOLOGY READINESS			
Innovativeness	INV1	I can usually figure out new hi-tech products and services without help from others.	Parasuraman and Colby [60], Burba *et al.,* [63], Van Der Rhee *et al.,* [95]
	INV2	In general, I am among the first in my circle of friends to acquire new technology when it appears.	
Optimism	OPT1	I like the idea of doing business via computers because we are not limited to regular business hours.	
	OPT2	Technology gives me more control over my daily life.	
	OPT3	Technology makes me more efficient in my occupation.	
TECHNOLOGY			
Relative advantage	RA1	The adoption of a solar PV system can provide better company environmental performance.	Lin and Ho [55], Lin *et al.,* [72], Ghobakhloo *et al.,* [73], Ali *et al.,* [96], Premkumar and Roberts [97]
	RA2	The adoption of a solar PV system can enhance the company's image.	
	RA3	The use of a solar PV system can provide competitive advantages for our company.	
	RA4	Introducing a solar PV system allows our company to save money.	
	RA5	The costs of a solar PV system are far greater than the benefits.	
	RA6	Introducing a solar PV system allows our company to reduce costs.	
	RA7	The initial setup cost of a solar PV system is very high for our company.	
	RA8	The cost of maintenance of a solar PV system is very high for our company.	
	RA9	Adopting a solar PV system is expensive for our company.	
ORGANISATION			
Organisational readiness	OR1	Our company has the financial resources to adopt a solar PV system.	Ocloo *et al.,* [81], Habiba *et al.,* [98]
	OR2	Our company has sufficient financial allocations to adopt a solar PV system.	
	OR3	Our company has a budget for staff to create awareness of the importance of solar PV system adoption.	
	OR4	Our company has the necessary expertise and skills to support a solar PV system adoption.	
ENVIRONMENT			
Government support	GS1	The government offers tax incentives to boost the adoption of a solar PV systems.	Ocloo *et al.,* [81], Chong *et al.,* [99]
	GS2	The government provides financial support for adopting a solar PV system.	
	GS3	The government has outlined regulations and laws for solar PV systems.	
	GS4	The government encourages the adoption of solar PV systems.	

5. Model Testing

Partial Least Squares (PLS) Structural Equation Modelling (SEM) analysis was conducted using the SmartPLS 4.0 software to perform statistical analysis. Unlike traditional regression analysis, which tests individual hypotheses one by one, SEM allows the testing of an overall model involving multiple latent variables simultaneously. SmartPLS is a popular technique in (IS) research by Marcoulides *et al.,* [100], especially when research is exploratory, and the number of constructs is relatively large. The software can handle complex models and works well with small to moderate sample sizes. Furthermore, using PLS is advantageous as it helps minimise the residual variances of the endogenous constructs, making it suitable for use in both small and large samples [101]. Thus, using SmartPLS can be beneficial for modelling latent variables in studies with small and medium sample sizes and non-normality.

The analysis followed a well-established procedure for PLS-SEM, which involves testing the measurement model first. The measurement model examines the relationship between the constructs and their respective items. The structural model's evaluation was conducted afterwards, examining the relationships between constructs. Figure 2 illustrates the flow and key considerations used for data analysis using PLS.

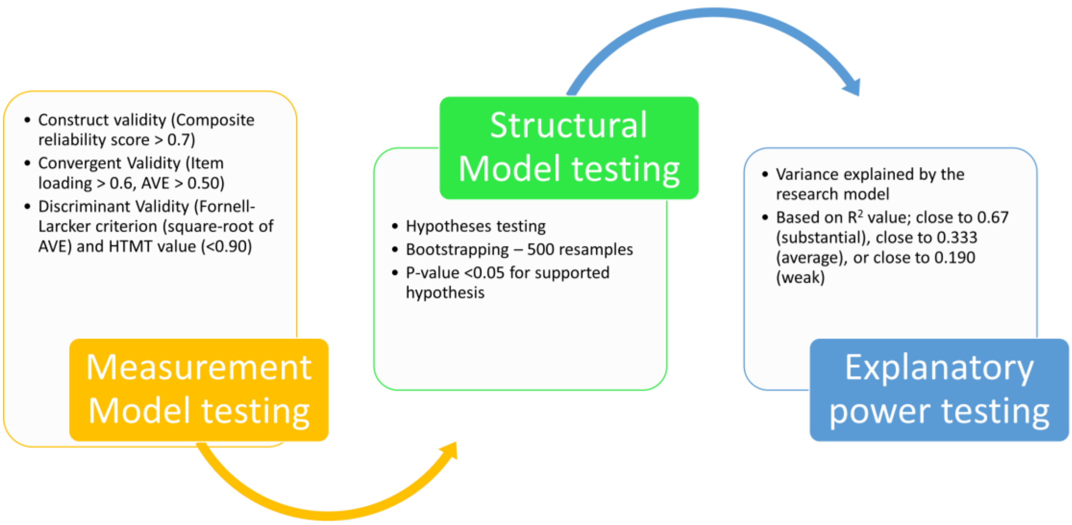

Fig. 2. Flowchart of data analysis using PLS

5.1 Assessment of the Measurement Model

The measurement model is evaluated by determining its construct validity, convergent validity, and discriminant validity. Construct reliability is assessed using a composite reliability score ranging from 0 (completely unreliable) to 1 (completely reliable). The construct is considered reliable when the composite reliability score exceeds the recommended value of .70 [102]. As shown in Table 4, the overall reliability score exceeds .70, indicating that the model is reliable.

The degree of correlation between indicators is called convergence validity [103]. Item loading is used to test convergence validity, and a recommended value of .60 indicates that they measure the same construct [102]. Since all items had loadings greater than the recommended value, none were removed from the final analysis. The AVE value of each construct is greater than the .50 threshold value proposed by Fornell and Larcker [104], indicating convergence validity.

Table 4
Item loadings for indicators of latent constructs

Latent Variable	Item	Loading	CR	AVE
Innovativeness (INN)	INN1	.949	.949	.902
	INN2	.951		
Optimism (OPT)	OPT1	.834	.943	.848
	OP2	.965		
	OPT3	.958		
Organisational Readiness (OR)	OR1	.977	.966	.876
	OR2	.979		
	OR3	.953		
	OR4	.828		
Government Support (GS)	GS1	.947	.893	.680
	GS2	.654		
	GS3	.740		
	GS4	.922		

Latent Variable	Item	Loading	CR	AVE
Relative Advantage (RA)	RA1	.945	.942	.732
	RA2	.885		
	RA3	.912		
	RA4	.915		
	RA5	.630		
	RA6	.807		
Solar PV Adoption (ADP)	ADP1	.711	.936	.748
	ADP2	.843		
	ADP3	.947		
	ADP4	.887		
	ADP5	.916		

Discriminant validity demonstrates that each construct is distinct. The authors used the Fornell-Larcker criterion and the Heterotrait-Monotrait ratio of correlations (HTMT) to assess discriminant validity. The square root of AVE is checked for the Fornell-Larcker criterion, and the correlation between all constructs is compared. As shown in Table 5, the square root of the AVE of each construct is greater than the cross-correlation between them, indicating discriminant validity [104]. Each indicator's loading is also greater than all of its cross-loadings [102].

Table 5
Discriminant validity (Fornell & Larcker)

	GS	INN	OPT	OR	RA	ADP
Government support (GS)	.825					
Innovativeness (INN)	.458	.950				
Optimism (OPT)	-.304	-.699	.921			
Organisational readiness (OR)	-.446	-.413	.128	.936		
Relative advantage (RA)	-.406	-.600	.708	.195	.856	
Solar PV adoption (ADP)	-.225	-.328	.592	.245	.609	.865

The HTMT results indicate that optimism (OPT) and innovativeness (INN) have the strongest correlation (.775) (Table 6). However, this value falls below the recommended threshold of .90, as suggested by Hair *et al.,* [105] and Henseler *et al.,* [106]. As a result, there is no discriminant validity problem.

Table 6
Discriminant validity (HTMT)

	GS	INN	OPT	OR	RA	ADP
Government Support (GS)						
Innovativeness (INN)	.514					
Optimism (OPT)	.221	.775				
Organisational Readiness (OR)	.555	.454	.116			
Relative Advantage (RA)	.381	.679	.771	.171		
Solar PV Adoption (ADP)	.223	.361	.635	.273	.613	

5.2 Assessment of the Structural Model

The structural model was evaluated by testing hypotheses with a bootstrap value of 500 resamples, as suggested by Sánchez-Franco and Roldán [107]. The results in Table 7 indicate that technology readiness variables (H1 and H2) and relative advantage (H3) play an important role in adopting PV solar. Nonetheless, the organisational (i.e., organisational readiness) and environmental factors (i.e., government support) were found to be insignificant (H4 and H5), which was surprising.

Table 7
Hypotheses testing

		β	SD	t-stat	p-value	Supported/ Not supported
H1	INN -> Adoption	.407	.157	2.594	.010[a]	Supported
H2	OPT -> Adoption	.556	.216	2.567	.011[b]	Supported
H3	RA -> Adoption	.428	.187	2.285	.023[b]	Supported
H4	OR -> Adoption	.284	.146	1.946	.052	Not Supported
H5	GS -> Adoption	.058	.165	.353	.724	Not Supported

[a]At an alpha significance level of .001 ($p < .001$).
[b]At an alpha significance level of .05 ($p < .05$).

Chin [108] proposed that R^2 values close to .67 should be considered substantial, while values close to .333 and .190 should be average and weak, respectively. Falk and Miller [109] added that the minimum R^2 value should be greater than 0.1 to ensure the nomological validity of the model. The R^2 value of 0.474 (as presented in Table 8) suggests that the research model explained 47.4% of the variance in solar PV adoption (hence, substantial). In other words, almost half of the variability in the dependent variable is explained by the independent variables in the study.

Table 8
R-square

	R-square
Solar PV adoption	.474

6. Discussion

The results of this study demonstrate that owners/managers of SMEs who possess traits of optimism ($\beta = .556, p < .05$) and innovativeness ($\beta = .407, p < .01$) are more likely to adopt solar PV technology in their businesses, irrespective of the cost and complexity associated with such adoption. The result implies that the companies will likely adopt solar PV if the owners/managers can explore and experiment with new ideas and innovations independently. In addition, companies whose the owners/managers are more proactive in considering an innovation have a greater tendency to install solar PV. The owners/managers with these characteristics are more inspired to become technology pioneers or leaders, thereby accelerating innovation [66].

The finding aligns with Ghobakhloo *et al.,* [73], who discovered that Iranian SMEs with more innovative CEOs were more willing to adopt electronic commerce. Similarly, Ahn *et al.,* [56] noted that key decision-makers in SMEs must exhibit innovative traits, which would enhance their willingness to take risks when needed. This study's positive outcome also aligns with Parasuraman and Colby's [60] findings that innovativeness and optimism enhance individuals' technology readiness.

Solar PV is considered relatively new and expensive to SMEs. Since SMEs are typically described as having limited technological and managerial capabilities, the owners'/managers' technological readiness is critical for promoting such innovation [65,110,111]. The respondents in this study held a generally positive outlook on the potential benefits of adopting solar PV technology, including greater flexibility, control, and effectiveness (i.e., optimism). Thus, the owners/managers who are more attracted to and optimistic about the potential value of a technology or innovation are more inclined to adopt solar PV. This finding corresponds to the study by Abdul Hameed and Counsell [112], which indicated that CEOs with optimistic traits are more inclined to pursue technological innovation. Moreover, the personality trait of optimism in SME CEOs could assist them in effectively assembling the necessary resources and expertise to facilitate the adoption of new technological applications [113].

Van Helmond and Kok [114] suggested that an organisation's awareness of the benefits of technology is crucial in deciding on adoption. Consistent with this notion, the present study discovered a positive association between relative advantage and the adoption of solar PV ($\beta = .428$, $p = < .05$). The finding indicates that Malaysian SMEs that perceive solar PV as having a relative advantage over traditional energy sources are more likely to adopt this technology. The firms foresee the potential benefits of solar PV outweighing the costs and challenges associated with adoption. Overall, the results demonstrated that companies that perceive greater benefits from solar PV deployment intend to adopt solar PV. The benefits could be in the form of better environmental performance, a good company image, and a higher level of competitiveness. Similarly, companies that perceive greater affordability of solar PV, specifically on the acquisition and maintenance costs, also tend to consider solar PV in their operation.

This result corresponds well with the previous research on various technologies adoption amongst SMEs, such as green innovation, green supply chain management, e-commerce, and big data analytics [72,73,85,115]. The study's finding also agrees with Ajah [116], who found the positive influence of perceived benefits on the attitude and intention of Nigerian MSMEs towards solar PV adoption. Hence, ensuring a competitive cost of renewable energy per unit in Malaysia helps SMEs foresee a greater relative advantage of alternative energy sources like solar PV [6].

This study does not have sufficient evidence on the effect of organisational readiness for solar PV adoption amongst SMEs in Malaysia. The absence of significance for organisational readiness (H4) ($\beta = .284$, $p > .05$) implies that it is not an important factor in explaining solar PV adoption among SMEs. The results demonstrated that having adequate financial resources, budget allocation, and the necessary technical skills do not affect companies' decision to adopt solar PV.

While this finding contradicts previous studies that emphasise the importance of organisational readiness in any innovation effort, some studies have found no significant relationship, such as Van Heck and Ribbers [117] on EDI adoption in Dutch SMEs and Gamage [118] on cloud computing in Sri Lankan SMEs [81,82,85].

One plausible explanation is the lack of planning and understanding of solar PV adoption amongst SMEs (as the respondents were non-adopters), making it difficult to assess the company's readiness. Even if the SMEs clearly understand the benefits of solar PV and are willing to adopt it, their readiness will be driven mainly by the process itself. Another possible explanation is that installing solar PV requires substantial modification to accommodate the solar panels on the building's rooftops. Although the companies are fully aware of the benefits of solar PV adoption, they may not have the authority to install solar panels on rented premises.

Finally, this study also found insufficient evidence for the role of government support (H5). Even though the stakeholders view government policies as one of the key strengths in Malaysia's renewable energy initiative, the present study found inadequate support for its impact on solar PV adoption amongst SMEs [6]. Hence, government support did not prove to be one of the important factors in determining SMEs' adoption of solar PV ($\beta = .058$, $p > .05$). The result aligns with previous studies conducted by Nugroho [119] and Satar and Alarifi [120] that were conducted on SMEs in developing economies, Indonesia and Saudi Arabia, respectively. As the results suggest, government support in the forms of tax incentives, financial assistance, formulation of regulations or laws, and continuous encouragement has no substantial effect on companies' intention to adopt solar PV.

One possible explanation in the context of solar PV adoption by SMEs is that these companies might not be fully informed or aware of the government's initiatives and policies related to renewable energy and solar PV systems. As non-adopters, they may not have had a strong incentive to seek information related to financing or other support initiatives.

In a nutshell, solar PV adoption amongst Malaysian SMEs is driven by the characteristics of owners/managers, specifically their innovativeness and optimism, and perceived relative advantage of solar PV to the companies compared to the expected cost incurred. Considering the SMEs' current state of solar PV adoption (non-adopters), perceived organisational readiness and government support play relatively insignificant roles in promoting solar PV adoption among SMEs in Malaysia.

7. Conclusion, Limitations, and Recommendations for Future Study

Malaysia's climate promises a brighter potential for solar PV as a primary renewable energy alternative in the next five years [121]. Given its potential, this study examined the role of owners'/managers' technology readiness (innovativeness and optimism), relative advantage, organisational readiness, and government support in adopting solar PV among Malaysian manufacturing SMEs. The results suggest that owners'/managers' technology readiness and relative advantage are important factors in explaining solar PV technology adoption amongst Malaysian manufacturing SMEs. However, the effects of organisational readiness and government support were not supported.

The findings of this study could have important implications for solar PV adoption by Malaysian manufacturing SMEs, as well as for similar contexts elsewhere. The important roles of owners'/managers' technology readiness and relative advantage in solar PV adoption provide valuable insights into the factors that drive solar PV adoption in Malaysian SMEs. Hence, more efforts should be made to capitalise on the firm's perceived benefits of the technology to encourage SMEs to adopt solar PV.

The lack of a significant effect of government support in solar PV adoption suggests that the government should explore additional ways to assist SMEs in taking the initiative. For example, campaigns could be launched to raise awareness among SMEs about the support and resources that the government provides to accelerate the adoption of solar PV. In addition, these valuable insights may assist green initiative policymakers (e.g., the government) and regulators (e.g., SEDA) in Malaysia to build effective strategies and incentives in promoting solar PV adoption by the manufacturing sector, thereby improving sustainable energy practises and lowering their reliance on non-renewable resources.

The study has several limitations. First, it employed a cross-sectional survey design that captured the respondents' views at a single point in time, making it impossible to infer causal relationships among the population. Hence, future research may consider using a longitudinal design to measure theoretical constructs at different points in time. Additionally, a mixed-method approach that includes qualitative techniques, e.g. interviews on top of the survey, could offer in-depth insights into the research findings.

Secondly, it is worth mentioning that this study only considered the motivator variables (innovativeness and optimism) when examining owners'/managers' technology readiness. Future studies could explore the inhibitors variables (insecurity and discomfort) to understand better the factors that affect technology readiness and identify barriers to solar PV implementation. In addition, additional variables, such as the adopters' post-solar PV intention or the effect of solar PV adoption on the adopters, may be considered.

Thirdly, the technological, organisational, and environmental factors covered in this study were limited to relative advantage, organisational readiness, and government support, respectively. Consequently, future studies could also consider other technological, organisational, and environmental factors that potentially explain solar PV adoption in SMEs. Taking into account other relevant factors could help to identify potential barriers to adoption and to design practical interventions to address the low adoption issue.

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